Basic Studies of Ion Sputtering

Scientific Achievement

Laser post ionization secondary neutral mass spectrometry (LPI SNMS) has been applied to the study of particle-solid interactions. When a keV ion impacts a surface, its energy is deposited near the surface causing atoms to be ejected in a process commonly called sputtering. The sputtered flux is mostly neutral atoms making the process difficult to study. Over the past twenty years, we have developed laser ionization methods that allow characterization of the sputtered flux. As part of a comprehensive study, experiments have been completed (1) to prove that sputtered neutral atoms and molecules mostly originate from the top most monolayer of a solid, (2) to measure the kinetic energy and angular distribution of sputtered neutral atoms and molecules for comparison with binary collision models, (3) to show that large neutral clusters are ejected during ion beam bombardment and (4) to demonstrate that molecules are sputtered with large amounts of internal energy but little electronic energy. These discoveries have formed the scientific basis for the development of LPI SNMS as a quantitative ultra-trace analysis tool that is unsurpassed in sensitivity. LPI SNMS instruments developed in our laboratory have been demonstrated to possess detection limits below 1 part per billion (10^{-9} atom fraction) for bulk analyses and 1 part per million (10^{-6} atom fraction) detection limits for micron-size particles and for single monolayer surface analysis.

Significance

Sputtering and particle-solid interactions are important physical phenomena that have wide spread technological applications ranging from semiconductor fabrication to thin film processing. Characterization of a sputtered flux is one of the few probes that can be used to obtain direct experimental evidence for comparison with models that describe deposition and distribution of energy during an ion impact. Because the flux consist mainly of neutral atoms and molecules, techniques developed at ANL are particularly important for testing such models. These studies and the resulting knowledge base have also contributed to improving LPI SNMS as a highly sensitive and quantitative analysis method. For example, knowledge of depth of origin of sputtered material is proof of the surface sensitivity of SIMS and SNMS analyses. Energy, angle and molecular abundance distributions contribute to improved quantification.

Understanding particle-solid interactions is just as important to nanotechnology as it has been to the semiconductor technology. Fundamental changes in particle-solid interactions as expected on the nanoscale compared to “macro” samples because the extent of a collision cascade (10-20 nm) will exceed the dimensions of an object. For nanoparticles, surfaces are no longer flat, consisting mainly of steps and terraces, so that ion impacts occur at various incident angles and ejection occurs in different directions. LPI SNMS may be the only technique with sufficient sensitivity to study the changes to particle-solid interactions that are expected to occur on the nanoscale.

Performers

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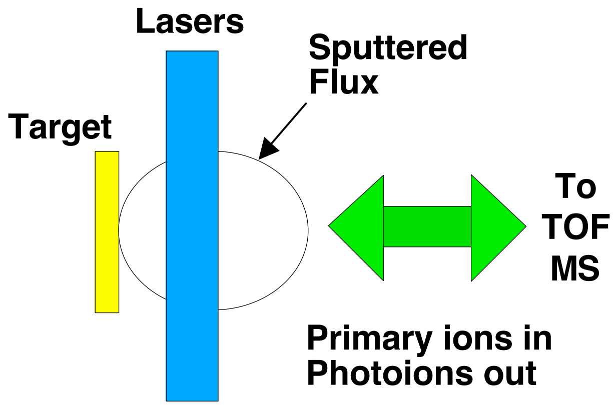
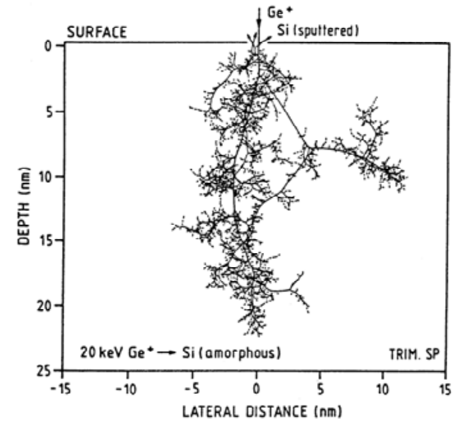
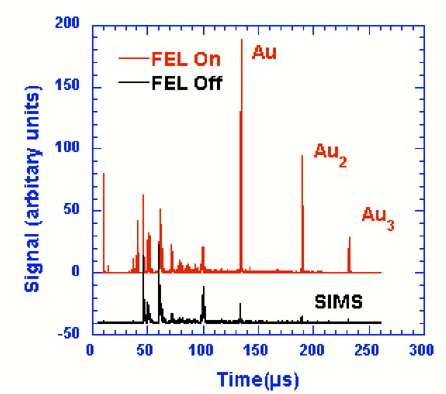
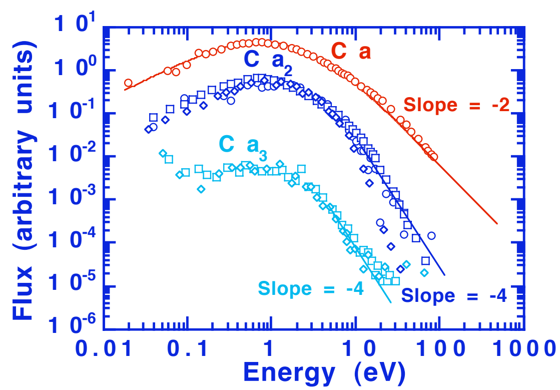


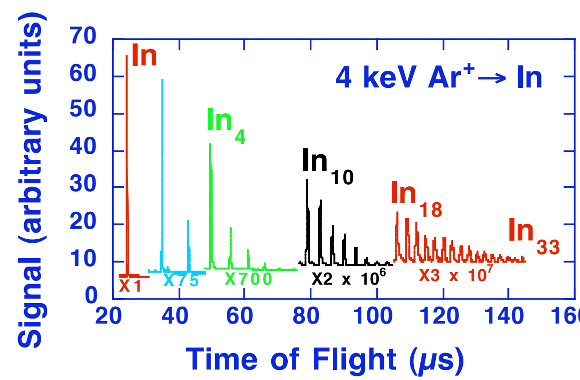
What happens when the size of an object is similar to the size of the collision cascade (10-20 nm) caused an ion impact?



The neutral flux from sputtered surfaces has been characterized in order to develop an understanding of particle-solid interactions for “macro” samples (previously measured and shown below) and for nanoscale objects as proposed for future research.







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